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Review

Forensic considerations of pregnancy-related maternal deaths: An overview

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ABSTRACT

During the 20th century, risks to women associated with childbirth in developed countries have been dramatically reduced on account of many factors that include technological advancements in obstetrical care, greater access to health services and fewer births occurring at the extremes of women's reproductive age span. However, pregnancy-related maternal deaths continue to be a major health concern in developing countries. In the year 2005, an estimated 536,000 women died of maternal causes worldwide of which 86% occurred in sub-Saharan Africa and South Asia and less than 1% in more developed countries. The large regional differences in maternal deaths demonstrate that most of these deaths are preventable. It is nevertheless important to monitor patterns of pregnancy-related mortality and serious morbidity and to be sensitive to what observed patterns or changes may tell us in order to continue to safeguard women during this critical period and the monitoring process must begin with ascertainment of the accuracy of routine reporting of deaths associated with pregnancy and childbirth. We examine the pregnancy-related maternal deaths with a forensic view point.

1. Introduction

Pregnancy-related maternal death is the death of a woman resulting from or related to her own pregnancy and/or postpartum condition. Maternal mortality as defined by the World Health Organization (WHO) is the death of a woman during pregnancy, childbirth or in the 42 days of the puerperium, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management. This definition includes deaths from abortion and ectopic pregnancy, but excludes deaths from incidental causes. Also excluded are deaths from assisted reproduction technologies where pregnancy has not occurred. International Classification of Diseases, tenth revision (ICD-10) defines pregnancy-related death as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death.[1]

Although pregnancy is considered a normal biologic process, it is associated with various physiologic and anatomic changes that place a woman at increased risk for death.[2] Maternal deaths may occur in the first, second or third trimester, during labour/birth, in the postpartum period, or any time after the postpartum period. Racial disparity of three to four times higher pregnancy-related mortality ratio among American blacks than those for whites has been reported.[3] Older women, particularly women aged more than 35 years and the women who received no prenatal care have also been found to have an increased risk for pregnancy-related death.[3] The present review aims to examine the prevalence, causes and the risk factors, and the approaches for measuring pregnancy-related maternal deaths with a forensic view point.

2. Prevalence of pregnancy-related maternal deaths

In the year 2000, a collaborative effort involving WHO, UNICEF and UNFPA reported 11 maternal deaths per 100,000 live births in the USA based on available data, with adjustments made for regional differences and inaccuracies in reporting and recording.[4] The Center for Disease Control and Prevention (CDC) reports a fairly static maternal mortality ratio (MMR – the risk of death once a woman has become pregnant) of approximately 7.5 maternal deaths per 100,000 live births,[3] while regional reports document the ratios as high as 22.8 per 100,000 live births.[5]

According to another analyses conducted by the Center for Disease Control and Prevention (CDC),[6] using the data from the Pregnancy Mortality Surveillance System, which includes information on all pregnancy-related deaths reported by state health departments, maternal mortality review committees, media and individual providers, more than 4000 US women died from pregnancy-related causes whereas 11.8 maternal deaths per 100,000 live births were pregnancy-related during the period 1991–1999. The risk of pregnancy-related death was sharply elevated among women aged 35 or older and among black women. The analysts classified a death as pregnancy-related if it occurred during or within one year after a pregnancy and resulted from complications

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Table 1
Prevalence of maternal mortality.

Name of the country	MMR per 100,000 live births
Malawi	1800
Ethiopia	850
India	540
Ghana	540
Peru	410
Bangladesh	380
Brazil	260
South Africa	230
Indonesia	230
Sri Lanka	92
Egypt	84
Mexico	83
Argentina	70
Russia	65
China	56
France	17
USA	14
UK	11
Norway	10
Finland	5

of the pregnancy, events triggered by the pregnancy or the pregnancy's aggravation of an unrelated condition.

According to a report from India, pregnancy-related complications account for the death of 301 women per 100,000 births despite all the maternal health programs and improvement in primary health care system.[7] In parts of Africa, maternal mortality rates are reported as high as 1 in 10 pregnancies in contrast to around one in 5000 in Sweden and Norway, representing an almost 500-fold difference, while in some developing countries the rates have been reported as one in 50.[8] Statistics reveal that the risk of death from complications of pregnancy decreased approximately 99% during the 20th century, from 850 maternal deaths per 100,000 live births in 1900 to 7.5 in 1982.[3] However, since 1982, no further decrease in maternal mortality has been reported.[3]

Recent estimates of maternal mortality ratios vary from more than 1000 per 100,000 live births in some the African countries, to around 500 in many countries in Asia, 200–400 in several countries in South America and less than 10 per 100,000 live births in some European countries,[9] showing great variations within the different regions (Table 1).

3. Common causes and risk factors for maternal deaths

According to a report,[6] the most common causes of pregnancy-related maternal mortality were embolism (accounting for 20% of deaths), hemorrhage (17%) and pregnancy-induced hypertension (16%), but substantial variation was evident by pregnancy outcome. For example, the leading cause of death was embolism among women who had a live birth (21%), hemorrhage among those who had a stillbirth (21%) and infection among those who had a spontaneous or induced abortion (34%). Nearly all deaths related to an ectopic pregnancy (93%) had resulted from hemorrhage; women who died while pregnant most often had medical problems such as cardiovascular, pulmonary or neurological conditions (34%). The report emphasized the need to further improve surveillance, identify the factors that contribute to excess maternal deaths among women and "develop effective strategies to prevent pregnancy-related mortality for all women, concluding that "substantial improvement" is needed to meet the government's Healthy People 2010 objective of reducing the level of maternal deaths to 3.3 per 100,000 live births – a goal that had earlier been set for the year 2000.

Maternal deaths have been generally classified into three groups[10]: (1) direct maternal deaths are those resulting from obstetrical complications of the pregnant state (pregnancy, labour and puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from any of the above—they are complications of the pregnancy itself (for example, eclampsia, amniotic fluid embolism, rupture of the uterus, postpartum hemorrhage); (2) indirect obstetric deaths are those resulting from preexisting disease or disease that developed during pregnancy and was not due to direct obstetrical causes, but which may have been aggravated by the physiological effects of pregnancy (for example, heart disease, diabetes and renal disease) and (3). Incidental deaths are those due to conditions occurring during pregnancy, where the pregnancy is unlikely to have contributed significantly to the death, although it is sometimes possible to postulate a distant association (for example, road accidents, malignancies and suicide). It is often difficult to decide whether a death is an indirect or an incidental death. For example, death from a self-administered overdose could be an accident or a suicide, and may or may not have been due to some effect on the woman of the pregnant state.

Such deaths not only continue to pose a wide scope of challenges to the health care policy planners but also to the forensic pathologist and the investigating agencies as they are difficult to identify precisely because this requires information about deaths among women of reproductive age, pregnancy status at or near the time of death, and the medical cause of death. All the three components can be difficult to measure accurately, particularly in settings where deaths are not comprehensively reported. Furthermore, even where overall levels of maternal mortality are high,

Table 2
Conditions unique to pregnancy.

Hemorrhagic conditions
Ruptured ectopic pregnancy
Placenta previa
Placenta abruption
Uterine rupture
Postpartum hemorrhage
Gestational hypertension (pregnancy induced hypertension)
Preeclampsia
Eclampsia
Embolic disorders
Amniotic fluid embolism
Trophoblastic tissue embolism
Others
Intrahepatic cholestasis of pregnancy
Acute fatty liver of pregnancy

Table 3
Conditions associated with pregnancy.

Pregnancy associated cardiac disorders
Peripartum cardiomyopathy
Peripartum myocarditis
Embolic disorders
Pulmonary thromboembolism
Air embolism
Thrombotic microangiopathies of pregnancy
Thrombotic thrombocytopenic purpura
Hemolytic uremic syndrome
Systemic lupus erythematosus
Endocrine disorders
Gestational diabetes mellitus
Pituitary insufficiency
Hyperpituitarism
Others
Infectious diseases
Gestational trophoblastic disease

Table 4
Conditions unrelated to but exacerbated by pregnancy.

Cardiac diseases
Congenital heart disease
Acquired valvular disease
Hypertensive cardiovascular disease
Atherosclerotic cardiovascular disease
Arrhythmogenic heart disease
Pulmonary diseases
Primary pulmonary hypertension
Asthmatic bronchitis
Hematologic diseases
Sickle cell anemia
Neurologic diseases
Arteriovenous malformation
Cerebral artery aneurism
Seizure disorder
Metabolic/endocrine diseases
Diabetes mellitus
Miscellaneous
Complications of anesthesia
Complications of surgery/instrumentation
Complications related to fetus – number, size or position

maternal deaths are relatively rare events and thus prone to errors in classification and measurement.[11]

Maternal mortality has been reported to be closely related to maternal age, with girls below 18 and women above 34 years of age being at a higher risk. Maternal deaths have also been reported to be more common in multiparous women, multiple pregnancies (twins or triplets etc.), and the women who have undergone IVF for infertility. Ethnicity has also been associated with maternal deaths and so is the social class and access to health care. Domestic violence in pregnancy is not only said to be associated with maternal and/or fetal death, severe morbidity, miscarriage, depression, suicide and drug abuse but also has profound short- and long-term effects on the child.[12]

Pathological conditions that may cause the death of a pregnant or postpartum woman are generally divided into three types: (1) conditions unique to pregnancy (Table 2), (2) conditions associated with pregnancy (Table 3) and (3) conditions unrelated to but exacerbated by pregnancy (Table 4).

4. Forensic considerations

4.1. A look at the definitions

The tenth revision of the International Classification of Diseases (ICD-10) defines a maternal death as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

The 42 day limit is somewhat arbitrary, and in recognition of the fact that modern life-sustaining procedures and technologies can prolong dying and delay death, ICD-10 introduced a new category, namely the late maternal death, which is defined as the death of a woman from direct or indirect obstetric causes more than 42 days but less than one year after termination of pregnancy.

According to ICD-10, maternal deaths should be divided into two groups:

1. Direct obstetric deaths are those resulting from obstetric complications of the pregnant state (pregnancy, labour and the puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from any of the above.
2. Indirect obstetric deaths are those resulting from previous existing disease or disease that developed during pregnancy and which was not due to direct obstetric causes, but was aggravated by physiologic effects of pregnancy.

The drawback of this definition is that maternal deaths can escape being so classified because the precise cause of death cannot be given even though the fact of the woman having been pregnant is known. Such under-registration is frequent in both developing and developed countries.

Deaths from "accidental or incidental" causes have historically been excluded from maternal mortality statistics. However, in practice, the distinction between incidental and indirect causes of death is difficult to make. To facilitate the identification of maternal deaths in circumstances where cause of death attribution is inadequate, ICD-10 introduced a new category, that of pregnancy-related death, which is defined as: the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death.

In practical terms then, there are two distinct approaches to identifying maternal deaths, one based on medical cause of death following the ICD definition of maternal death, and the other based on timing of death relative to pregnancy, that is, using the ICD definition of pregnancy-related death. This may have important implications for the reporting of maternal deaths.

4.2. Difficult to measure

Maternal mortality is difficult to measure for both conceptual and practical reasons. Maternal deaths are hard to identify precisely because this requires information about deaths among women of reproductive age, pregnancy status at or near the time of death, and the medical cause of death. All three components can be difficult to measure accurately, particularly in settings where deaths are not comprehensively reported through the vital registration system and where there is no medical certification of cause of death. Moreover, even where overall levels of maternal mortality are high, maternal deaths are nonetheless relatively rare events and thus prone to measurement error. As a result, all existing estimates of maternal mortality are subject to greater or lesser degrees of uncertainty.

Broadly speaking, various countries throughout the world, fall into one of four categories:

1. Those with complete civil registration and good cause of death attribution – though even here, misclassification of maternal deaths can arise, for example, if the pregnancy status of the woman was not known or recorded, or the cause of death was wrongly ascribed to a non-maternal cause.
2. Those with relatively complete civil registration in terms of numbers of births and deaths but where cause of death is not adequately classified; cause of death is routinely reported for only 78 countries or areas, covering approximately 35% of the world's population.
3. Those with no reliable system of civil registration where maternal deaths – like other vital events – go unrecorded. Currently, this is the case for most countries with high levels of maternal mortality.
4. Those with estimates of maternal mortality based on household surveys, usually using the direct or indirect sisterhood methods. These estimates are not only imprecise as a result of sample size considerations, but they are also based on a reference point some time in the past, at a minimum 6 years prior to the survey and in some cases much longer than this.

WHO, UNICEF and UNFPA have developed estimates of maternal mortality primarily with the information needs of countries

with no or incomplete data on maternal mortality in mind, but also as a way of adjusting for underreporting and misclassification in data for other countries. A dual strategy is used that adjusts existing country information to account for problems of underreporting and misclassification and uses a simple statistical model to generate estimates for countries without reliable data.

5. Approaches for measuring maternal mortality

Commonly used approaches for obtaining data on levels of maternal mortality vary considerably in terms of methodology, source of data and precision of results. As a general rule, maternal deaths are identified by medical certification in the vital registration approach, but more often, it is done on the basis of the time of death definition relative to pregnancy in household surveys (including sisterhood surveys), censuses and in reproductive age mortality studies (RAMOS).

6. Vital registration

In developed countries, information about maternal mortality derives from the system of vital registration of deaths by cause. Even where coverage is complete and all deaths medically certified, in the absence of active case-finding, maternal deaths are frequently missed or misclassified.[13–17] In many countries, periodic confidential enquiries or surveillance are used to assess the extent of misclassification and underreporting. A review of the evidence shows that registered maternal deaths should be adjusted upward by a factor of 50% on average. Few developing countries have a vital registration system of sufficient coverage and quality to enable it to serve as the basis for the assessment of levels and trends in cause-specific mortality including maternal mortality.

7. Direct household survey methods

Where vital registration data are not appropriate for the assessment of cause-specific mortality, the use of household surveys provides an alternative. However, household surveys using direct estimation are expensive and complex to implement because large sample sizes are needed to provide a statistically reliable estimate. The most frequently quoted illustration of this problem is the household survey in Addis Ababa, Ethiopia, where it was necessary to interview more than 32,300 households to identify 45 deaths and produce an estimated MMR of 480. At the 95% level of significance this gives a confidence interval of plus or minus about 30%, i.e. the ratio could lie anywhere between 370 and 660.[18] The problem of wide confidence intervals is not simply that such estimates are imprecise. They may also lead to inappropriate interpretation of the figures. For example, using point estimates for maternal mortality may give the impression that the MMR is significantly different in different settings or at different times whereas, in fact, maternal mortality may be rather similar because the confidence intervals overlap.

8. Indirect sisterhood method

The sisterhood method is a survey-based measurement technique that in high-fertility populations substantially reduces sample size requirements because it obtains information by interviewing respondents about the survival of all their adult sisters. Although sample size requirements may be reduced, the problem of wide confidence intervals remains. Furthermore, the method provides a retrospective rather than a current estimate, averaging experience over a lengthy time period (some 35 years, with a midpoint around 12 years before the survey).[19] For methodological reasons, the indirect method is not appropriate for use in settings where fertility levels are low [total fertility rate (TFR) < 4] or where there has been substantial migration, civil strife, war, or other causes of social dislocation.

9. Direct sisterhood method

The demographic and health surveys (DHS) use a variant of the sisterhood approach, the "direct" sisterhood method.[20] This relies on fewer assumptions than the original method but it requires larger sample sizes and the information generated is considerably more complex to collect and to analyze. The direct method does not provide a current estimate of maternal mortality but the greater specificity of the information permits the calculation of a ratio for a more recent period of time. Results are typically calculated for a reference period of seven years before the survey, approximating a point estimate some three to four years before the survey. Because of relatively wide confidence intervals, the direct sisterhood method cannot be used to monitor short-term changes in maternal mortality or to assess the impact of safe motherhood programs. The demographic and health surveys have published an in-depth review of the results of the DHS sisterhood studies (direct and indirect methods) and have advised against the duplication of surveys at short time-intervals.[21] WHO and UNICEF have issued guidance notes to potential users of sisterhood methodologies, describing the circumstances in which it is or is not appropriate to use the methods and explaining how to interpret the results.[22]

10. Reproductive age mortality studies

The reproductive age mortality study (RAMOS) involves identifying and investigating the causes of all deaths of women of reproductive age. This method has been successfully applied in countries with good vital registration systems to calculate the extent of misclassification and in countries without vital registration of deaths.[17,23–26] Successful studies in countries lacking complete vital registration use multiple and varied sources of information to identify deaths of women of reproductive age as no single source identifies all the deaths. Subsequently, interviews with household members and health care providers and reviews of facility records are used to classify the deaths as maternal or otherwise. Properly conducted, the RAMOS approach is considered to provide the most complete estimation of maternal mortality but can be complex and time-consuming to undertake, particularly on a large scale.

11. Standard of care

It needs to be emphasized that the planning and delivery of maternity services should focus on approaching each woman as an individual with different social, physical and emotional needs, as well as specific clinical factors that may affect her pregnancy. The pregnancy must not be viewed in isolation from other important factors that may influence the health of a pregnant woman. A continuing risk assessment of the pregnant woman, first at booking and then at each point of contact throughout the antenatal, intrapartum, and postpartum periods is of great significance.

Substandard care remains difficult to evaluate and quantify in these cases due to lack of key data in case records and notes, however, despite these limitations, it has been reported that 50% of direct deaths and 17% of indirect deaths are associated with substandard care to the extent that a different treatment would have affected the outcome.[27] In most cases, antenatal care is shared between the general practitioner, community or clinic midwife and the obstetrician depending upon the availability of resources, and so are the deliveries conducted at home, primary health

centers, maternity clinics and the secondary and tertiary care centers. With so much variation in the system, an appropriate referral/transfer of the patient for specialist care may be overlooked, resulting in maternal deaths. The main causes of substandard care may include:

1. lack of communication and team work or poor liaison between professionals;
2. failure to appreciate the severity of illness and sub-optimal treatment;
3. wrong diagnosis;
4. failure of junior staff or general practitioners to diagnose and/or refer the case to a hospital or senior colleague;
5. failure of consultants to attend and inappropriate delegation of responsibility (telephonic consultations);
6. failure of consultants to identify a disease or condition that does not commonly occur in their specialty or to seek early appropriate advice;
7. lack of intensive care facility, blood products, or a clear policy for the prevention or treatment of conditions such as pulmonary embolism, eclampsia or massive hemorrhage.

Furthermore, reduction in the number of maternal deaths in relation to pregnancy and childbirth can be achieved through improvement of emergency care and reduction in delays of seeking care, through improvement of antenatal care, and through general health promotion and disease prevention activities.[28] The causes of a maternal death have been classified into three phases of delay[29]:

(1) Phase 1, failure of a patient to seek appropriate medical care in time.
(2) Phase 2, delay in reaching an adequate health care facility.
(3) Phase 3, delay in receiving adequate health care at the facility, including delay in referral.

Hoestermann et al. [30] found that 51% of the maternal deaths at the maternity unit of the main tertiary level hospital in Gambia were related to Phase 3 delays. Similarly, in Dar es Salaam, 72 of 93 maternal deaths in a referral hospital were related to sub-optimal medical care.[31]

Phase 3 delay will influence delay in the two other phases.[32] It is even unethical to encourage women to seek treatment for problems related to pregnancy if obstetric services do not exist or do not function. In Tanzania, a recent study found that the main barrier to use of quality obstetric care was not the mother's ignorance or ability to get to the facility. The actual quality of care and the critical services provided and the inequitable distribution of qualified staff between urban and rural areas were of greater importance.[33–35]

Phase 2 delay is often due to lack of transport or low quality of roads, which is commonly a problem in many areas, especially in the rainy season. Development of a referral system and a system of transport and communication between peripheral areas and the facilities where emergency treatment can be given can significantly reduce maternal mortality.[36]

Phase 1 delay can be reduced through community education with information, targeted to women as well as to men, about the importance of pregnancy care and the necessity of seeking care in time.

12. Place of delivery

Proportion of births attended by skilled health personnel represents the percentage of all births attended by a skilled health care worker. The term "skilled attendant" refers to "an accredited health professional – such as a midwife, doctor or nurse – who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period, and in the identification, management and referral of complications in women and newborns".[37]

13. Termination of pregnancy/miscarriage

Unsafe abortion refers to the termination of an unintended pregnancy either by persons lacking the necessary skills or in an environment lacking the minimal medical standards, or both.[38] Approximately one in eight maternal deaths is estimated to result from an unsafe abortion.[39] A global estimate of the incidence of unsafe abortion suggests that approximately 20 million unsafe abortions take place every year, nearly 90% of which take place in the developing world. The typical complications of unsafe abortions are sepsis, hemorrhage, uterine perforation and lower genital tract injuries.

To address the problem of unsafe abortion, the UNDP/UNFPA/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP):

(1) monitors the prevalence of, and trends in, unsafe abortion and associated mortality;
(2) develops new or improved methods of family planning for regular or emergency use;
(3) assists countries to broaden the choice of family planning methods and improve the quality of care in family planning services;
(4) assists countries to identify and prioritize needs related to preventing unsafe abortion and strengthening reproductive health; design and implement action research to address priority needs; and scale-up successful policy and program innovations;
(5) provides guidance on the management of complications of unsafe abortion;
(6) develops safe alternative approaches to pregnancy termination;
(7) formulates evidence-based technical and policy guidance on safe abortion.

14. Autopsy

The autopsy is essential in supporting clinical audit and clinical governance and its value has been demonstrated in early studies that revealed clinical discrepancies in up to 30% of cases with approximately one third of these being major discrepancies that would have influenced clinical management. Even despite recent improvements in diagnosis and management technology, a recent study has found significant clinical discrepancies in about 15% of cases.[40]

A thorough evaluation of pregnancy-related maternal deaths includes gathering medical and obstetrical history, performing and/or reviewing various laboratory tests, and performing a complete autopsy with histopathological examination and toxicological analysis keeping in mind a long list of conditions unique to pregnancy, associated with pregnancy and those unrelated to but exacerbated by pregnancy.

Where medical certification of cause of death is not available, some studies assign cause of death using verbal autopsy techniques.[41] However, the reliability and validity of verbal autopsy for assessing cause of death in general and identifying maternal deaths in particular, has not been established. The method may fail to correctly identify a proportion of maternal deaths, particularly

those occurring early in pregnancy (ectopic, abortion-related), those in which the death occurs some time after the termination of pregnancy (sepsis, organ failure), and indirect causes of maternal death (malaria, HIV/AIDS).

15. Conclusion

The healthy people 2000 objective for maternal mortality of no more than 3.3 maternal deaths per 100,000 live births was not achieved during the 20th century and substantial improvements are needed to meet the same objective for healthy people 2010. However to achieve the goal a structured approach is needed to:

1. Improve knowledge on the magnitude/burden of leading causes of maternal morbidities and mortality.
2. Develop tools to improve monitoring of maternal health.
3. Determine the extent of underreporting of maternal mortality.
4. Determine cause-specific death rates and to compare these rates with cause-specific death rates among women not known to have been pregnant within the preceding year.
5. Explore approaches to defining and quantifying serious pregnancy-related morbidity.
6. Document trends and/or regional differences in defined indicators of serious pregnancy-related morbidity.
7. Identify areas that require more intensive action.

Conflict of interest

None declared.

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